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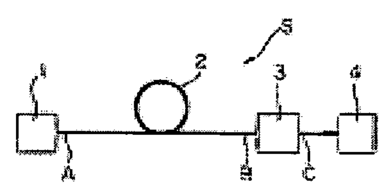
(54) (Name of the invention) Optical soliton transmission method

(57) (Summary)
(Structure) This application covers a transmission method of optical soliton that uses optical soliton formed in the wavelength range of negative group velocity dispersion of optical fiber, characterized in which in the event of optical loss in Optical fiber 2, modulation in frequency of optical soliton pulse due to optical loss is compensated using Light dispersion compensation device 3 of group velocity dispersion of the opposite sign to the above Optical fiber 2. Further, optical soliton pulse can be amplified by using light amplifier after the modulation of frequency is compensated by using the light dispersion compensation device, and more than one layer of light transponder that is equipped with light dispersion compensation method of the opposite sign to the optical fiber, and light amplification method.

(Effect) It is possible to extend the distance which optical soliton pulse can be transmitted without relaying. Moreover, it is also possible to extend the installation spacing interval between light amplifiers and light transponder, enabling light soliton transmission in multi-transfer at high information transmission rate. Consequently, it enables long distance, super fast, high capacity optical communication at economical cost.



(Patent claim)

(Claim 1) In optical soliton transmission method that uses optical soliton formed in the wavelength range of negative group velocity dispersion of single mode optical fiber, optical soliton transmission method characterized in which in the event of optical loss in Optical fiber for transmission of optical soliton, modulation in frequency of optical soliton pulse due to said optical loss is compensated using Light dispersion compensation device that has group velocity dispersion of the opposite sign to said single mode optical fiber.

(Claim 2) In optical soliton transmission method described in Claim 1, optical soliton characterized in which optical soliton pulse is amplified using optical amplifier after the modulation of frequency is compensated by using said light dispersion compensation device.

(Claim 3) In optical soliton transmission method that uses optical soliton formed in the wavelength range of negative group velocity dispersion of single mode optical fiber, optical soliton transmission method characterized in which in the event of optical loss in Optical fiber for transmission of optical soliton, modulation in frequency of optical soliton pulse due to said optical loss is compensated, as well as optical soliton pulse is amplified, using more than one layer of light transponder that is equipped with light dispersion compensation method of the opposite sign to the optical fiber, and light amplification method.

(Detailed description of the invention)

(0001)

(Applicable field in industry) This invention is related to transmission method of optical soliton, particularly transmission method of optical soliton which enables long distance, super fast, high capacity optical communication at economical cost by compensating modulation in frequency of optical soliton pulse due to light transmission loss through transmission path.

(0002)

(Conventional art) In the case of performing high capacity optical communication, it is necessary to increase transmission capacity by reducing the pulse width of the optical pulse used for transmission, but because commonly used silica type single mode optical fiber has group velocity dispersion property and optical loss wavelength property in which zero dispersion area exists near the range of wavelength at 1.32μm, when linear shaped optical pulse, said pulse width grows wide due to the effect of group velocity dispersion that exists in optical fiber, and the amount of growth is more substantial in smaller pulse width. With the current technology, it is difficult to increase transmission capacity any more, and thus, high capacity optical communication is limited.

(0003) In order to increase the transmission capacity of optical pulse, it is necessary to overcome waveform expansion due to the effect of group velocity dispersion and waveform distortion caused by high order dispersion, and in 1973, Hasegawa and Tappert showed in theory that optical soliton transmission becomes possible by balancing the group velocity dispersion in optical fiber and the effect of self-phase modulation (Reference 1:A. Hasegawa and F. Tappert, Appl. Phys. Lett., 23(1973) 142.).

(0004) Optical soliton that is formed in abnormal dispersion wavelength region has a characteristic that if there is no transmission loss (optical loss) through optical fiber, it is transmitted through this optical fiber without changing waveform due to balancing of expansion by group velocity dispersion and compression due to nonlinear optical effect (optical Kerr effect). Because of this, transmission method using optical soliton is a very promising method to realize long distance, high capacity optical communication.

(0005) However, because optical fiber in practical use has a slight optical loss (light weakens 0.22dB/km in wavelength range of 1.55μm, approximately 5% at 1 km), even optical soliton reduces in amplitude of optical pulse, resulting in expanding of pulse width, which leads to changing of waveform.

(0006) Conventionally, in order to compensate for the change in waveform of optical soliton caused by this optical loss, a method of transmitting optical soliton has already been proposed in which amplifier effect is given to the optical transmission path in distributive constant form using stimulated Raman scattering, creating optical transmission path that is equivalently lossless. (Reference 2: A. Hasegawa, Appl. Opt. 23, P. 3302 (1984). Reference 3: L. F. Mollenaner, J. P. Gordon, and M. N. Islam, IEEE J. Quantum Electron. QE22, p.157 (1986).).

(0007) This method is particularly suitable for transmission over long distance because it is able to provide ideal optical soliton transmission path.

(0008) Further, a method of transmitting optical soliton over long distance has been proposed, in which the optical transmission path is not given amplification effect, but the optical amplifiers are installed throughout the optical transmission path at a certain interval, thereby compensating for the loss of optical fiber in lumped constant way. (Reference 4: Kubota, Nakazawa, Suzuki, Kokai number (1989) 68619 bulletin, Reference 5: H. Kubota and M. Nakazawa, IEEE J., Quantum Electron. QE26, p. 692 (1990).).

(0009) This method is a optical transmission method that is highly practical, because the region that has the amplifier effect can be localized and the structure is simple.

(0010)

(Problems to be resolved by the invention) And now, the optical soliton transmission method described above that uses stimulated Raman scattering is suitable for long distance transmission of optical soliton pulse because it is able to provide ideal optical soliton transmission path, but there are also shortcomings, that the structure of the overall system is very complex, and it is not possible to have lossless optical soliton transmission path at any selected location because it is difficult to have uniform amplified transmission gain over the entire optical transmission path. Moreover, relatively small size of transmission gain by stimulated Raman scattering is also a shortcoming.

(0011) Further, although optical soliton transmission method that uses optical amplifier enables localization of the range of values that has amplification effect, making the structure of the overall system much simpler and therefore having higher possibility, the relaying distance of optical transmission path is limited because the intensity of optical soliton pulse decreases by optical loss of optical fiber due to heavily utilizing the change in waveform as nonlinear pulse of high intensity optical soliton, and the interval between optical amplifiers in said optical transmission path cannot be longer than approximately 50 km, making it difficult to extend the installation interval of optical amplifiers further.

(0012) The present invention was achieved in consideration of the above matters, and the aim of the invention is to provide an optical soliton transmission method in which long distance, super fast, high capacity optical communication is possible at economical cost, where attention is focused on not only compensation on the reduction in intensity of optical soliton pulse as in conventional approach but on compensation of frequency modulation (phase change), enabling extension of transmission distance of optical soliton or installation interval of optical amplifier for optical soliton transmission by compensating frequency modulation of optical soliton pulse caused by optical transmission loss through optical soliton transmission path, using optical dispersion compensation device that has the group velocity dispersion of the opposite sign of the single mode optical fiber.

(0013)
(Means of solving the problem) To solve the above problems, the present invention employs the following optical soliton transmission method.

(0014)
That is, as optical soliton transmission method described in Claim 1 of the present invention, in optical soliton transmission method that uses optical soliton formed in the wavelength range of negative group velocity dispersion of single mode optical fiber, it is optical soliton transmission method characterized in which in the event of optical loss in Optical fiber for transmission of optical soliton, modulation in frequency of optical soliton pulse due to said optical loss is compensated using Light dispersion compensation device that has group velocity dispersion of the opposite sign to said single mode optical fiber.

(0015) Further, as optical soliton transmission method described in Claim 2 of the present invention, in optical soliton transmission method described in Claim 1, it is optical soliton characterized in which optical soliton pulse is amplified using optical amplifier after the modulation of frequency is compensated by using said light dispersion compensation device.

(0016) Moreover, as optical soliton transmission method described in Claim 3 of the present invention, in optical soliton transmission method that uses optical soliton formed in the wavelength range of negative group velocity dispersion of single mode optical fiber, it is optical soliton transmission method characterized in which in the event of optical loss in Optical fiber for transmission of optical soliton, modulation in frequency of optical soliton pulse due to said optical loss is compensated, as well as optical soliton pulse is amplified, using more than one layer of light transponder that is equipped with light dispersion compensation method of the opposite sign to the optical fiber, and light amplification method.

(0017)
(Operation of the invention) In the optical soliton transmission method described in Claim 1 of the present invention, the effect of optical soliton is used in the initial region of the transmission, and when the intensity of optical soliton pulse decreases due to optical transmission loss of optical fiber for transmission, linear pulse is used for transmission. Then, by compensating the frequency modulation and expansion of pulse width of optical soliton pulse due to group velocity dispersion caused at linear sections during optical soliton transmission by using optical dispersion compensation device which has group velocity dispersion of the opposite sign to said single mode optical fiber, distance in which lossless transmission of optical soliton pulse is possible (distance in which optical signal can be transmitted without converting to electric single) is extended by permitting expansion of the pulse width of optical soliton pulse in transmission, and the installation interval of optical amplifier and transponder used in optical soliton transmission is extended.

(0018) Further, in optical soliton transmission method described in Claim 2, in optical soliton transmission method described in Claim 1, light distribution sensitivity of optical soliton pulse is improved by amplifying the optical soliton pulse after the compensation of frequency modulation by the above optical dispersion compensation device, extending the distance in which lossless transmission of said optical soliton pulse is possible even further, and also extending the installation interval of optical amplifier and transponder used in optical soliton transmission.

(0019) Moreover, in optical soliton transmission method described in Claim 3, by using more than one layer of optical transponder that is equipped with method of optical dispersion compensation that has group velocity dispersion of the opposite sign to the above single mode optical fiber and method of optical amplifier, frequency modulation of optical soliton pulse due to the above optical transmission loss is compensated, and at the same time, said optical soliton pulse is amplified to improve the intensity of said optical soliton pulse, thereby extending the distance in which lossless transmission is possible even further, and enabling long distance, multi-transfer optical soliton transmission.

(0020)
(Embodiment) The following is a description of each illustrative embodiment of the present invention with figures.

(0021) Figure 1 is a diagrammatic illustration which shows the composition of an embodiment of the optical soliton transmission method described in Claim 1 of the present invention, Optical soliton transmission system S, and Figure 2(a)-(o) is an illustration which indicates a diagram of waveform of optical soliton pulse at each section of optical transmission path A-C in Figure 1.

(0022) In Figure 1, 1 indicates an optical soliton generator, 2 indicates an optical fiber for optical soliton transmission (optical fiber), 3 indicates an optical dispersion compensation device, and 4 indicates an optical receiver.

(0023) Optical soliton generator 1 generates optical soliton pulse in wavelength range of 2.55μm, and for example, soliton laser that is comprised of mode synchronizing F center laser and polarization maintaining single mode fiber is preferably optimally.

(0024) Optical fiber 2 is, for example, silica type single mode optical fiber which has group velocity dispersion property and optical loss wavelength property in which zero dispersion area exists near the range of wavelength at 1.32μm.

(0025) Optical dispersion compensation device 3 has group velocity dispersion of the opposite sign to the above optical fiber 2, and it compensates the frequency modulation and expansion of pulse width due to group velocity dispersion caused at linear regions of the optical fiber during optical soliton transmission.

(0026) For this optical dispersion compensation device 3, for example, in the case of the wavelength area at 1.5μm off the optical soliton pulse that is used, silica type dispersion shift fiber in which group dispersion wavelength is shifted to the long wavelength side from 1.5μm (having positive group velocity dispersion), GT interferometer, Fabry-Perot resonator, and also

optical fiber and optical waveguide that uses Lithium niobate ($LiNbO_3$), rutile type titanium dioxide (TiO_2; or titania), or Tellurium dioxide (TeO_2) and crystals thereof, are preferably used.

(0027) Optical receiver 4 receives the optical soliton pulse that is compensated by optical dispersion compensation device 3 and then converts to electrical signal, and for example, Avalanche Photodiode is preferably used.

(0028) Next, description of the operation of the optical soliton transmission system S is given.

(0029) First, electrical signal is converted to optical soliton pulse by optical soliton generator 1, and then input said optical soliton pulse to optical fiber 2 and transmit through said optical fiber 2.

(0030) Optical soliton pulse is initially highly intense and shows a small waveform (Figure 2 (a)) when it enters the optical fiber 2, but as it is transmitted through said optical fiber 2, intensity decreases as well as non linearity decreases due to optical loss of said optical fiber 2. Further, pulse width expands because of negative group velocity dispersion that optical fiber 2 has, and starts to have frequency modulation (chirping) (Figure 2 (b)).

(0031) In this state, adjacent optical soliton pulse overlaps each other and it would be impossible to detect each individual signal.

(0032) These deformed optical soliton pulse recovers pulse width by going through optical dispersion compensation device 3, and frequency modulation is also compensated (Figure 2 (c)). This optical soliton pulse has a reduced intensity (less than 1/100 in the example), but the waveform is the same (similar figure) as the initial state. With this, overlapping optical soliton pulse are clearly separated, enabling detection of the signal again.

(0033) After the recovery of the pulse width, optical soliton pulse is converted to electrical signal by optical receiver 4, and is extracted as signal.

(0034) Figure 3 shows an example of the result of simulation analysis performed with a calculator in order to confirm the effect of dispersion compensation of optical soliton pulse in the optical soliton transmission system S of the above embodiment.

(0035) In this figure, state of change in the waveform of optical soliton pulse is shown in the case of setting dispersion compensation amount (ps/nm) of the optical dispersion compensation device as the parameter.

(0036) Here, it is assumed that half value width τ [illegible] of optical soliton is 10ps, wave length is 1.55μm, length of optical fiber is 100km, optical transmission loss is 0.24dB/km, and group velocity dispersion is -2.0 ps/km/nm.

(0037) Furthermore, the dash line in the figure indicates, as a reference, waveform of the input optical soliton pulse that is not distorted. As stated above, the pulse intensity changes in the factor of more than 100 before and after the transmission, so it shows at reduced size.

(0038) With this result, the pulse width is wider and the pulse height is lower in the case of optical pulse that is not dispersion compensated (the amount of dispersion compensation is 0 ps/nm), but the pulse width decreases as the amount of dispersion compensation increases, and it can be seen that at 160 ps/nm of the dispersion compensation amount, the waveform is recovered to almost the same form as the input optical soliton pulse. Further, when the amount of dispersion compensation is higher than 180 ps/nm, the waveform is deformed to the other side, indicating that dispersion compensation is not possible if the amount of dispersion compensation exceeds a certain value.

(0039) Figure 4 indicates another example of the result of simulation analysis by a calculator that was performed to confirm the effect of this invention and is a diagram that indicates relationship between the pulse width of optical soliton pulse and the amount of dispersion compensation.

(0040) In the figure, the horizontal axis shows dispersion compensation (ps/nm), and the vertical axis shows pulse width (PS).

(0041) Here, it is assumed that half value width τ [illegible] of optical soliton is 10ps, wave length is 1.55μm, optical transmission loss is 0.24dB/km, group velocity dispersion is -2.0 ps/km/nm, and three cases of the length of optical fiber (Z), 60, 80 and 100km.

(0042) From this result, it can be seen that even in the case of different lengths of the optical fiber (transmission distance), it is possible to adjust the dispersion compensation amount to recover the pulse width of the optical soliton pulse in which the pulse width is changed to almost the same pulse width to the input optical soliton pulse.

(0043) Figure 5 is a diagram that indicates the result of simulation analysis to confirm the effect of the present invention in the case of inputting and transmitting the optical soliton pulse pairs to the optical fiber, and it corresponds to Figure 2.

(0044) Here, it is assumed that pulse interval of the optical soliton pulse pairs is 50 ps, half value width τ [illegible] of each pulse is 10ps, wave length is 1.55μm, length of optical fiber is 100km, optical transmission loss is 0.24dB/km, and group velocity dispersion is -2.0 ps/km/nm.

(0045) From this result, it is not possible to detect individual signal in the case of no dispersion compensation because optical pulse overlaps each other, but when the amount of dispersion compensation is 160 ps/nm, optical soliton pulse pairs was cleanly separated, and it is possible to identify individual signal clearly. Further, it can be seen that when the amount of dispersion compensation is higher than 180 ps/nm, the waveform is deformed, making dispersion compensation impossible.

(0046) As described above, with the optical soliton transmission system S of this embodiment, frequency modulation of optical soliton pulse due to optical transmission loss is compensated by using optical dispersion compensation device 3 that has group velocity dispersion of the opposite sign to the optical fiber 2, enabling compensation of frequency modulation and expansion of pulse width of the optical soliton pulse due to group velocity dispersion occurred at linear sections of optical soliton pulse during transmission, thus permitting expansion of pulse width of optical soliton pulse during transmission and extending the distance of possible lossless transmission of the relevant optical soliton pulse.

(0047) Moreover, with this optical soliton transmission system S, optical soliton pulse has higher intensity than linear pulse so it excels in signal to noise ratio (S/N ratio), and further, it is possible to transmit over longer distance for the same S/N ratio. In addition, as long as the effect of soliton is maintained even locally, occurrence of both change in the waveform and frequency modulation (chirping) is smaller than linear pulse (with ideal optical soliton, waveform does not change, and frequency modulation does not occur), and the amount of optical dispersion compensation needed for the transmission over the same distance is smaller than the transmission that uses linear pulse.

(0048) Moreover, this optical soliton transmission system S can be combined with lumped constant optical amplifier, and with multi transfer optical soliton transmission that uses this combination, it is possible to extend the installation interval of the optical amplifier, and at the same time, it is possible to extend the distance of non relaying transmission compared to the system that does not use this method. In this case, laser diode amplifier, erbium (Er) dope optical fiber amplifier and others are preferred as optical amplifier.

(0049) As shown above, it is possible to extend the transmission distance of optical soliton and provide optical soliton transmission method which enables economical long distance, super fast, high capacity optical communication.

(0050) Figure 6 is a illustrative diagram that indicates composition of an embodiment of optical soliton transmission method described in Claim 3 of the present invention, the multi transfer optical soliton transmission system M.

(0051) In the multi transfer optical soliton transmission system M, optical transponder 5 is connected after the optical fiber 2, and with this optical transponder 5, frequency modulation of optical soliton pulse caused by optical transmission loss is compensated and at the same time, optical intensity is amplified, and this series of action is repeated multiple layers (from N_1 to N_N layer).

(0052) With this multi transfer optical soliton transmission system M, optical soliton generator 1, optical fiber 2, and optical receiver 4 are exactly the same as the components of the above optical soliton transmission system S, so description for these components are omitted, and description of optical transponder 5, which is different from the above component, is given.

(0053) Optical transponder 5 is equipped with optical dispersion compensation mean 6 and optical amplification mean 7.

(0054) Optical dispersion compensation mean 6 has group velocity dispersion of the opposite sign to the above optical fiber 2, and it compensates the frequency modulation and expansion of pulse width of the optical soliton pulse due to group velocity dispersion caused at linear section during optical soliton transmission.

(0055) For this optical dispersion compensation mean 6, like optical dispersion compensation device 3 of the previous embodiment, for example, in the case of the wavelength area at 1.5μm off the optical soliton pulse that is used, silica type dispersion shift fiber in which group dispersion wavelength is shifted to the long wavelength side from 1.5μm (having positive group velocity dispersion), GT interferometer, Fabry-Perot resonator, and also optical fiber and optical waveguide that uses Lithium niobate ($LiNbO_3$), rutile type titanium dioxide (TiO_2; or titania), or Tellurium dioxide (TeO_2) and crystals thereof, are preferably used.

(0056) Optical amplification mean 7 amplifies the optical intensity of optical soliton pulse in which intensity is decreased due to optical transmission loss of optical fiber 2, and for example, for pulse in the wavelength range of 1.5 μm, laser diode amplifier, erbium (Er) dope optical fiber amplifier and others are preferably used.

(0057) For the above optical amplification mean 7, it is not necessary to limit the type of optical amplifier if no advanced functions are needed, but in particular, in the case of pushing the limit, preamp type is preferably for optical amplifier that is installed before optical receiver 4 to improve reception sensitivity, and in addition, main amp type is preferably for optical amplifier that is installed before optical fiber 2 to obtain large optical soliton pulse.

(0058) Next, description of the operation of this multi transfer optical soliton transmission system M is given.

(0059) Pulse width of optical soliton pulse that is sent to the first layer (N_1) of optical fiber 2 by optical soliton generator 1 is recovered and frequency modulation is compensated by optical dispersion compensation mean 5 of optical transponder 5, and optical intensity is amplified by optical amplification mean 6, recovering the intensity of optical soliton pulse which is decreased due to optical loss of optical fiber 2.

(0060) Optical soliton pulse that has recovered intensity is then sent to the second layer (N_2) of optical fiber 2, then like as described above, pulse width is recovered and frequency modulation is compensated by optical dispersion compensation mean 5 of optical transponder 5, and optical intensity is amplified by optical amplification mean 6, recovering the intensity of optical soliton pulse which is decreased.

(0061) And below, optical dispersion compensation and optical amplification is performed repeatedly at optical transponder 5 of each layer, and after sent to the final layer (N_2) of optical fiber 2, like as described above, pulse width is recovered, frequency modulation is compensated, optical intensity is recovered, and then it is converted back to electrical signal b optical receiver 4, and extracted as signal.

(0062) Figure 7 shows an example of the result of simulation analysis performed with a calculator in order to confirm the effect of dispersion compensation and optical amplification of optical soliton pulse in the multi transfer optical soliton transmission system M of the above embodiment.

(0063) In Figure 7, optical soliton pulse pairs is used for input, and state of change in the waveform of the pulse on the output side of optical transponder 5 of each layer in Figure 6, is shown.

(0064) Here, it is assumed that pulse interval of each optical soliton pulse is 50 ps, half value width τ [illegible] of each pulse is 10ps, wave length is 1.55μm, pulse interval is 5500 ps, length of each optical fiber is 100km,

optical transmission loss of each is 0.24dB/km, group velocity dispersion is -2.0 ps/km/nm, and the amount of dispersion compensation is 160 ps/nm. This amount of dispersion compensation is the same as the optimal value of Figure 3.

(0065) Furthermore, Figure 8 indicates the waveform of pulse that is multi transfer transmitted in the conventional method under the same condition as Figure 7, shown in the same method as Figure 7 for comparison purpose. However, the length of each optical fiber is 25 km.

(0066) From this result, it can been seen that unlike with the conventional method in which the transmission distance is short and the waveform is substantially reduced, the method of this embodiment enables clear identification of individual signal as the optical soliton pulse pairs are cleanly separated, and transmission of clean optical soliton pulse pairs at high capacity transmission rate (high bit rate) over more than 2000 km in total length.

(0067) Further, distance of each optical fiber (the installation interval of optical amplifier) can be more than twice by using this method (4 times as in the example), allowing economical optical soliton communication over long distance transmission with a small number of optical amplifiers.

(0068) As described above, with the multi transfer optical soliton transmission system M of the above embodiment, more than one layer of light transponder 5 that is equipped with a light dispersion compensation method 6 of the opposite sign to the optical fiber and a light amplification method 7 is used to compensate the frequency modulation of optical soliton pulse due to optical transmission loss, as well as to recover the reduced intensity of said optical soliton pulse, by amplifying the optical soliton pulse, and now it is possible to extend the transmission distance of optical soliton with no relaying even further and extend the installation interval of the optical transponders 5 in the optical soliton transmission, thus enabling multi transfer optical soliton transmission at high capacity transmission rate (high bit rate) over more than 2000 km in total length.

(0069) Like this, it is possible to extend the installation interval of the optical amplifiers in the optical soliton transmission, providing with the optical soliton transmission method which enables economical implementation of long distance, super fast, high capacity optical communication.

(0070) Incidentally, with the multi transfer optical soliton transmission system M, location of installation of optical dispersion compensation device can be either (1) output end of the optical fiber, or (2) output end of the optical amplifier, providing with the exact same effect in both cases.

(0071) Further, optical dispersion compensation device does not need to be a separate device, that is, for example, it is possible to include the dispersion property to optical amplifier, forming the composition that doubles as dispersion compensation device.

(0072) In addition, in all cases of the above embodiments, the pulse width of input optical soliton pulse is about 1.5 times the normal case, and methods of the above References 4 and 5 to extend the transmission distance are used at the same time.

(0073) Also, the intensity of the output optical soliton pulse from the optical soliton generator or the optical transponder can be either amplitude $A = 1$, or amplitude $A > 1$ (above References 4, 5), and even higher extension effect of the relaying distance can be expected in the case of $A > 1$.

(0074)
(Effect of the invention) As described above, with the optical soliton transmission method described in Claim 1 of the present invention, in the method of optical soliton transmission that uses optical soliton that is formed in the wavelength region of negative group velocity dispersion of the single mode optical fiber, if there is optical transmission loss in the optical fiber for transmission of optical soliton, frequency modulation of the optical soliton pulse due to said optical transmission loss is compensated by using optical dispersion compensation device that has the group velocity dispersion of the opposite sign to said single mode optical fiber, and this compensates the frequency modulation and expansion of pulse width of the optical soliton pulse due to group velocity dispersion caused at linear sections during transmission of optical soliton pulse, allowing expansion of the pulse width of the optical soliton pulse during transmission, thus enabling to extend the distance which transmission of said optical soliton pulse without relaying is possible.

(0075) Accordingly, it is now possible to provide with the optical soliton transmission method which allows long distance, super fast, high capacity optical communication economically.

(0076) Further, with the optical soliton transmission method described in Claim 2, in which with the optical soliton transmission method described in Claim 1, optical soliton pulse is amplified by optical amplifier after frequency modulation is compensated by the above optical dispersion compensation device, improving the reception sensitivity of the above optical soliton pulse, thus extending the distance which transmission of said optical soliton pulse without relaying even further.

(0077) Accordingly, it is now possible to extend the installation interval of the optical amplifiers in the optical soliton transmission and to provide with the optical soliton transmission method which allows long distance, super fast, high capacity optical communication economically.

(0078) Furthermore, with the optical soliton transmission method described in Claim 3, in which with the optical soliton transmission method that uses optical soliton that is formed in the wavelength region of negative group velocity dispersion of the single mode optical fiber, if there is optical transmission loss in the optical fiber for transmission of optical soliton, by using more than one layer of the optical transponders that are equipped with both the optical dispersion compensation mean that uses group velocity group velocity dispersion of the opposite sign to said single mode optical fiber and the optical amplification mean, the frequency modulation of the optical soliton pulse due to said optical transmission loss is compensated, as well as said optical soliton pulse is amplified, recovering the intensity of said optical soliton pulse and allowing to extend the distance which transmission of said optical soliton pulse without relaying even further, thus enabling multi transfer optical soliton transmission at high capacity transmission rate (high bit rate).

(0079) Accordingly, it is now possible to extend the installation interval of the optical transponders in the optical soliton transmission, providing with the optical soliton transmission method which enables economical implementation of long distance, super fast, high capacity optical communication.

(Brief description of figures)

(Figure 1) It is a diagrammatic illustration which shows the composition of an embodiment of the optical soliton transmission method described in Claim 1 of the present invention, Optical soliton transmission system S.

(Figure 2) It is an illustration which indicates a diagram of waveform of optical soliton pulse at each section of optical transmission path A-C in Figure 1.

(Figure 3) It is an illustration which indicates the relationship between the dispersion compensation amount and optical soliton pulse waveform in an embodiment of the present invention, the optical soliton transmission system S.

(Figure 4) It is an illustration which indicates the relationship between the pulse width of the optical soliton pulse and the dispersion compensation amount in an embodiment of the present invention, the optical soliton transmission system S.

(Figure 5) It is an illustration which indicates the relationship between the dispersion compensation amount and waveform of the optical soliton pulse pairs in an embodiment of the present invention, the optical soliton transmission system S.

(Figure 6) It is an illustration which indicates the composition of a multi transfer optical soliton transmission system M that is an embodiment of the optical soliton transmission described in Claim 3 of the present invention.

(Figure 7) It is an illustration which indicates the state of change in the waveform of the pulse on the output side of the optical amplifiers of each layer of an embodiment of the present invention, the multi transfer optical soliton transmission system M.

(Figure 8) It is an illustration which indicates the state of change in the waveform of the pulse on the output side of the optical amplifiers of each layer of the conventional multi transfer optical soliton transmission system.

(Explanation of the symbols)

S	Optical soliton transmission system
1	Optical soliton generator
2	Optical fiber for optical soliton transmission (Optical fiber)
3	Optical dispersion compensation device
4	Optical receiver
M	Multi transfer optical soliton transmission system
5	Optical transponder
6	Optical dispersion compensation mean
7	Optical amplification mean
$N_1 \sim N_N$	Layers

Fig. 1

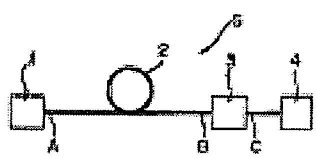


Fig. 2

Fig. 4

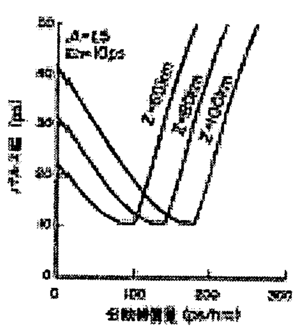


Fig. 3

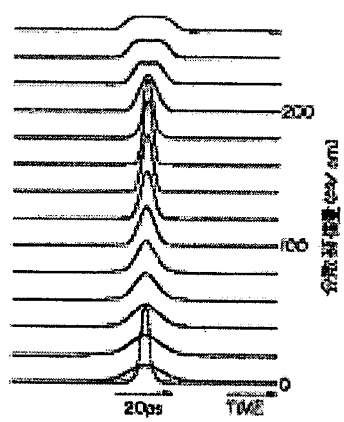


Figure 3
Dispersion compensation amount (ps/nm)

Figure 4
Dispersion compensation amount (ps/nm)

Fig. 5 【図5】

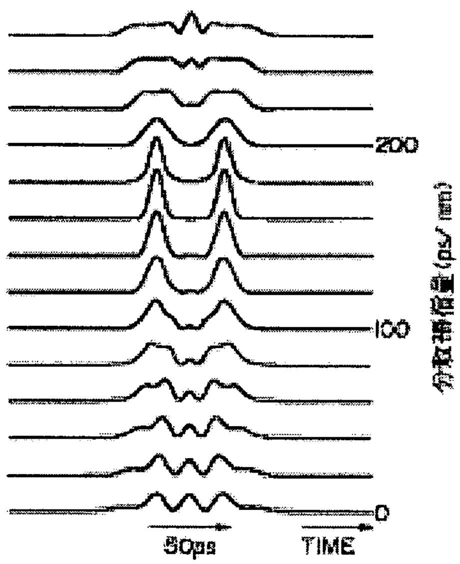


Fig. 7 【図7】

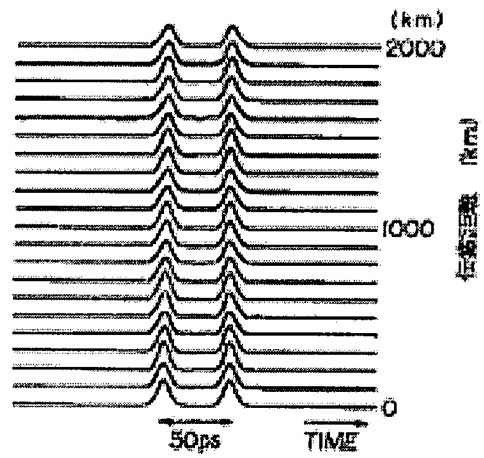


Figure 5
Dispersion compensation amount (ps/nm)

Figure 7
Transmission distance (km)

Fig. 6 【図6】

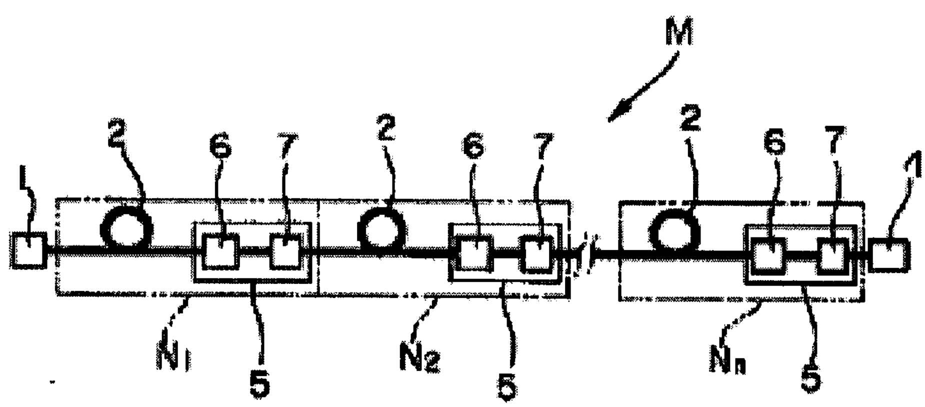


Fig. 8

【図8】

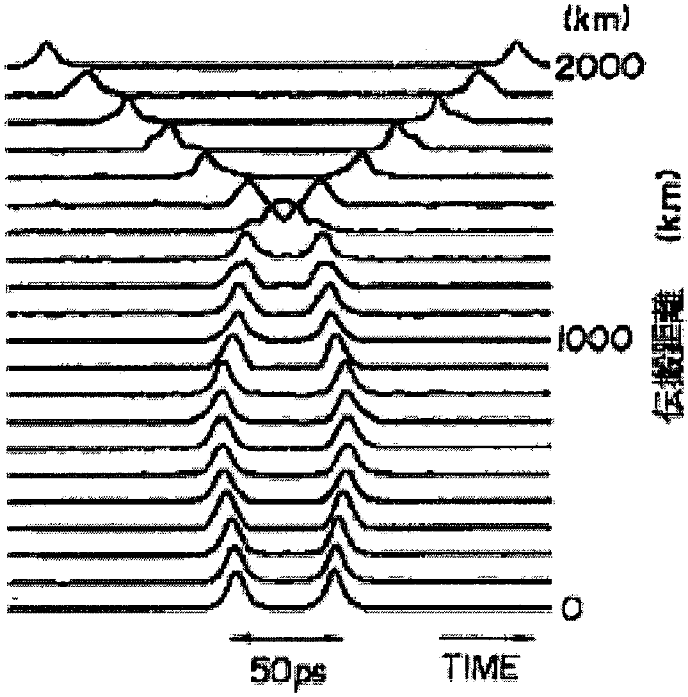


Figure 8

Transmission distance (km)